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Marine Highway Transport of Toxic Inhalation Hazard (TIH) Materials

By

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ABSTRACT

This paper presents highlights of research conducted under Phase 2 of NCFRP 17 North American Marine Highways in order to investigate the possibility of transporting greater volumes of chlorine and anhydrous ammonia via the marine highway system. Currently, there is no coastwise and limited inland waterway activity related to either. The researchers identified the major obstacles to development and expansion and corresponding potential courses of action. Geographical dispersion of producers and consumers works against greater waterborne volumes. Both chemicals are characterized by mature, low-growth markets. Expansion of marine services will require significant capital costs and time to set up new terminals. There is great concern over the condition of the current system of locks and dams. Marine carriers, absent any action by the federal government, face the same economic ramifications from risk of catastrophic accidents faced by rail carriers, necessitating the establishment of a new risk paradigm. The federal government could provide initial funds and expedite the permitting process to allow new marine highway ventures to develop more rapidly. It could also identify and assist potential new import points for both chemicals into the U.S. Finally, the federal government must indicate its commitment to maintain the current inland waterway system. However, there are no measures that can overcome the geographical dispersion of producers and users, the lack of density in any given corridor, and the fact that the markets are mature. Therefore, significant expansion of TIH materials transportation via marine highways is not anticipated.
INTRODUCTION

In the first phase of this research effort, North American Marine Highways, the authors suggested further research into the possibility of diverting heavy and hazardous shipments to water. From an environmental and public safety viewpoint this would appear desirable, especially given the rail industry’s eagerness to absolve itself from its common carrier obligations related to these materials on one hand, and the demonstrated efficiency of marine highways on the basis of several performance measures, on the other. After reviewing the research recommendations, the project panel appointed by the Transportation Research Board determined that this additional research should be undertaken as Phase 2 of the initial study. This paper presents highlights and summarizes the findings from this research.

The specific objective of this research was to develop a business case for transporting a larger share of chlorine and anhydrous ammonia shipments via the marine highway system than is currently shipped. Both of these products are classified as toxic inhalant hazard (TIH) materials. The business case considered the following issues: market definition; return on investment; obstacles; impacts on other modes and their likely reactions; labor issues; environmental concerns and benefits directly related to the transport of the two commodities; risks; regulatory, security, infrastructure, and vessel requirements; transportation congestion impacts; and lessons learned from international experience (Europe and Canada).

The underlying question driving this research effort was the following: If the market favors marine transportation, why isn’t marine transportation already expanding? In attempting to answer this question and identify the factors that inhibit the growth of the system, the authors researched the following topics:

- Nature of the cargo (anhydrous ammonia and chlorine)
- Current delivery systems and practices
- Motivation for encouraging more waterborne shipments
- Experience of Europe and Canada in this area
- Vessel requirements and associated capital expenditures
- Currently available fleets for rail, truck, and marine
- Economic issues
- Major obstacles to further development and expansion
- Potential courses of action

For purposes of this study, the marine highway marketplace was limited to U.S. domestic movements and shipments between the U.S. and Canada. In the case of export or import shipments, the port of entry or exit was treated as the source or destination of the movement. This included inland waterway movements and coastwise movements.

The researchers encountered a scarcity of literature that specifically dealt with the elements and issues related to developing a business case for the transport of TIH materials. In order to obtain the latest and most accurate information, a data and information “mining” exercise took place which was complemented with interviews of several executives involved in the production and/or distribution of anhydrous ammonia or chlorine (i.e., chlorine and fertilizer manufacturing, marine highway initiatives, railroads, shipyards, and the towing industry).

Ammonia and chlorine are pervasive in everyday life. Agricultural industries are the major users of ammonia, accounting for over 85% of all ammonia produced in the U.S. Ammonia (nitrogen) is the nation’s dominant commercial fertilizer and is used either directly in
anhydrous form or indirectly in manufactured fertilizers. Chlorine is an essential component in 45% of all commercial products. The major uses of chlorine (in descending order of quantities used) include the manufacturing of organic compounds, manufacturing of vinyl chloride to make polyvinyl chloride (PVC) plastics, manufacturing of inorganic chemicals, water treatment, and bleaching of pulp and paper.

Ammonia is widely used throughout the U.S. agricultural areas and thus, like chlorine, must be transported from a limited number of production and import locations to the broad geography of U.S. agricultural production areas. Most chlorine is shipped from production locations directly to consumption sites. Users tend to be widely dispersed and do not typically consume large amounts of chlorine at any given site. Roughly two-thirds of chlorine is never shipped but rather is used on-site in chemical manufacturing or is moved by pipeline to nearby facilities.

COMMODITY FLOWS

Over 2.2 billion tons of hazardous materials valued at $1.4 trillion were transported in the U.S. in 2007, the latest year for which comprehensive data were available, with each shipment moving an average of 96 miles (1). The average shipment distance decreased from 136 miles in 2002. The literature indicated that the distance hauled has decreased due to greater co-location of suppliers and consumers (2). In 2007, 26.9 million tons of TIH (1.2% of the total hazardous materials tonnage) were moved by all modes, of which 18.2 million tons consisted of ammonia and chlorine (3). (Table 1)

TABLE 1 Volume of Ammonia and Chlorine Shipments in 2007

<table>
<thead>
<tr>
<th>Mode</th>
<th>Ammonia (000 tons)</th>
<th>Chlorine (000 tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck</td>
<td>9,257</td>
<td>NA</td>
</tr>
<tr>
<td>Rail</td>
<td>1,141</td>
<td>3,241</td>
</tr>
<tr>
<td>Inland Barge</td>
<td>1,536*</td>
<td>109</td>
</tr>
<tr>
<td>Pipeline</td>
<td>2,896</td>
<td>NA</td>
</tr>
<tr>
<td>Total</td>
<td>14,830</td>
<td>3,350</td>
</tr>
</tbody>
</table>

NA=Not Available   *Includes ammonia in anhydrous state and in aqueous solution

Peak anhydrous ammonia production in the U.S. occurred in 1998 at 16.8 million tons sold, plus approximately 7 million tons used to make nitrogen-based fertilizers at production facilities. In 2010, the U.S. Census Bureau reported ammonia production of 11.1 million short tons and imports of 7.4 million short tons, with U.S. producers operating at about 85% of their rated capacity (4). The figures were higher than in 2009 — domestic production of 10.3 million short tons and imports of 6.1 million short tons. Exports were negligible in both years (5). Since 1998, the U.S. has been importing greater amounts of anhydrous ammonia (including nitrogen-based fertilizers) and producing less domestically because the price of natural gas has been lower in other producing countries. Figure 1 shows that ammonia production facilities are typically co-located with their raw material source (import terminals or shale gas plays) or with major markets (agricultural regions). Destinations include distribution terminals that are typically located at major agricultural regions and sparsely located user plants. There are two ammonia
pipelines—one runs from Texas to Minnesota and the other from Louisiana to Nebraska and Indiana. There is no domestic coastwise movement of anhydrous ammonia at present.
According to statistics from the Chlorine Institute, in 2008 the U.S. chlor-alkali industry (effectively four major companies) produced 11.5 million short tons of chlorine and 12.1 million short tons of caustic soda (sodium hydroxide) (6). Most TIH chemicals are shipped from production locations directly to consumption sites (although some are produced, stored, and used at a single site). Chlorine, for example, is produced at chemical plants mostly concentrated in the southern part of the country (Figure 2), from which it is shipped to customer sites, such as water purification plants and other chemical plants. Chlorine producers also ship to chlorine packaging locations and sodium hypochlorite bleach production facilities. Additional destinations include PVC plastics producers, some paper mills, and chemical manufacturers. Roughly two-thirds of chlorine is never shipped but rather is used on-site in chemical manufacturing or is moved by pipeline to nearby facilities. Users tend to be widely dispersed and do not typically consume large amounts of chlorine at any given site. The only major chlorine-receiving terminal using inland waterway transportation is located in New Johnsonville, Tennessee. Economic factors favor rail transportation of chlorine, and indeed the vast majority of chlorine shipments in the U.S. are shipped by rail. The other safe and practical mode for long-distance transportation of chlorine is barge which is indeed considered safer than rail but is less available and more restrictive in its ability to reach as many origins and destinations. Trucking companies are reluctant to offer long-haul chlorine transportation services. There is presently no identifiable coastwise shipment of bulk liquefied chlorine by water.

![Map of Major Chlorine Production Sites](image)

**FIGURE 2** Major chlorine production sites.

The producers of both anhydrous ammonia and chlorine tend to locate near their principal feedstock source and low-cost energy supply; hence, they tend to cluster within a region. Choice of transportation mode depends primarily on locations of supply and consumption. It is also influenced by the size of individual shipments. Where possible, economics generally favor bulk...
transportation of basic materials such as ammonia and chlorine, which inherently favors high-volume modes such as marine or rail.

**FINDINGS (OBSTACLES)**

**Geographical Dispersion**

This is the most formidable obstacle to a significant increase in the volume of TIH marine shipments. As noted above, producers tend to cluster, but consumers tend to be widely dispersed throughout the country.

Since natural gas is the primary feedstock and by far the most important cost component in the production of ammonia, new shale gas plays might result in the construction of ammonia production facilities in new locations, which would in turn affect commodity flows. To-date, no ammonia producer has announced any intention to build a facility near one of these plays. Even if they were to do so, it is unlikely that waterborne transportation would be part of the logistics chain, given the location of these new plays.

There is very little concentration of chlorine shipments between any origin-destination pair. With the announced intention of the chlorine industry to co-locate more production facilities adjacent to consumer facilities, and with a widespread initiative underway to substitute safer products for chlorine, the likelihood of additional concentration or new high-volume corridors developing is minimal at best.

**Financial Risk of Catastrophes**

The railroads purchase insurance to mitigate the financial risk of carrying hazardous materials, but this coverage is both expensive and limited in availability. According to the Association of American Railroads (AAR), highly hazardous commodities constitute only 0.3% of the total carloads but account for 50% of the insurance costs of railroad companies (7). Any marine carrier wishing to enter the chlorine transportation marketplace will have to determine if the economic benefits of the transportation operation will outweigh the cost of insurance against catastrophic accidents. According to the AAR, the revenue that highly hazardous materials generate for the railroads does not come close to covering the potential liability to railroads associated with transporting this traffic.

**Operational**

The Surface Transportation Board (STB) noted in recent proceedings that barge companies lack sufficient barge capacity and there is insufficient storage capacity (the shipper’s responsibility) to handle a significant shift of anhydrous ammonia traffic from pipeline to barge; barge transport involves higher costs than pipeline transport, which could make a shift prohibitively expensive; barges, unlike pipelines, are hindered by floods, low water, and icing; and barge trips take from days to weeks, while pipeline injection and withdrawal is essentially instantaneous. Some of the qualitative considerations found to limit the effectiveness of barge competition were capacity, reliability, speed, and safety. Because of insufficient storage capacity at barge destination points, prohibitively large expenditures or investments would have to be made in order to shift from pipeline to barge (8).
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Producers cannot store chlorine. This means chlorine moves from the manufacturing site to the consuming location and into the production process immediately with only nominal inventory on site. The ideal solution in this environment is to build consuming plants or locations at the production site. One of the chlorine producers interviewed for this study indicated that marine possibilities are limited by customer locations, lack of marine routes, absence of marine docks and storage facilities, and insufficient demand for the bulk quantities that can be economically delivered (typically 1,100 short tons per barge).

Marine ammonia terminals must be capable of receiving and holding anhydrous ammonia in a refrigerated state, loading out to refrigerated barges, and reheating ammonia to feed non-refrigerated pipelines, rail cars, and trucks. It currently requires about three years to start up a new terminal. Marine shipments of chlorine are severely limited by the number of facilities capable of receiving it by barge. There are currently only two such facilities on U.S. inland waterways and no coastwise shipments. In the interviews conducted for this study, the capital cost of equipment and infrastructure was cited several times as the most important limiting factor for marine shipments. A switch to chlorine transportation by water requires suppliers and end users to invest large amounts of capital for infrastructure. Representative costs for new facilities and equipment can help provide perspective on the economics of capital requirements:

- Ammonia refrigerated storage terminal (30,000 tons): $20M
- Ammonia pressurized storage tank (30,000 gallons): $150,000
- Ammonia barge (2,500-3,000 tons): $14M-$15M
- Ammonia unit tow: 2 or 3 times the cost of 1 ammonia barge
- Chlorine barge (1,100 tons): $6M
- Chlorine infrastructure: $5M-over $100M
- Towboat: $5M-$6M

A further complication for both chlorine and ammonia shipments is the fact that in the northern reaches of the river system (especially the Upper Mississippi River), ice is a problem in the winter. The Upper Mississippi River above Quincy, Illinois, closes annually from December to March/April, and navigation is often restricted on the Illinois River in January and February. The fact that chlorine cannot be stored in sufficient quantities to last the winter becomes a severe operational and financial constraint for logistics managers.

**Regulatory**

The current regulatory environment tends to discourage new market entrants. For example, accidents involving TIH materials have no liability limits. A single hazardous materials accident can bankrupt a small carrier.

Several of the interviewees for this study indicated that one of the biggest obstacles to building new transportation and storage facilities is the permitting process. The uncertainty of the time it will take to acquire the permit and then construct the project makes a rapid response to market shifts very difficult.

Jones Act requirements that restrict domestic service to vessels with a U.S. flag, with a U.S. crew, and constructed in the U.S., make coastal movements an impossibility in the short run. There are no suitable Jones Act vessels involved in coastal trade, and the cost to convert existing vessels would be prohibitive. Interviewees made the case that there is no need to move anything along the coast anyway. If port facilities were available, imports would be made...
directly by foreign-flag vessels and then shipped by barge, rail, or pipeline to the ultimate destination.

**Market**

A start-up enterprise or an expanding operation will need to consider two major market risks. The first is that manufacturers may begin substituting for TIH materials to avoid the risks and transportation expenses and difficulties. This is already happening with chlorine-based producers, the most notable being Clorox®. The other major risk is that producers may actively seek to cluster their facilities to avoid having to transport TIH materials over significant distances. A new proposed chlorine plant in New Johnsonville, Tennessee, to feed the existing titanium dioxide plant is an example of such a strategy. In other words, users of ammonia and chlorine may begin relocating to sites closer to producers, thereby eliminating transportation altogether.

The ammonia marketplace has shown itself to be sensitive to external factors such as natural gas prices that can vary dramatically over relatively short periods of time. Investment in such infrastructure is therefore uncertain and appears unlikely in the current regulatory environment with lengthy permitting processes and easy substitution via imports.

U.S. fertilizer demand is not expected to grow much at all—it is a mature market. There is only so much available land, and only so much fertilizer can be put on that land. Interviewees indicated that the volumes for 2010 and 2011 are probably close to the ceiling for the U.S. In other words, this market is a mature market with few, if any, existing service gaps.

Chlorine demand is not expected to decrease significantly, despite the industry’s status as a “mature business.” Given the importance of chlorine-derived products in a modern economy (ranging from basic construction materials such as PVC to refrigerants, bleaches, agricultural chemicals, water purification, and many other applications), it is unlikely that overall chlorine use will significantly decline, despite a perception that chlorine is environmentally unfriendly. Nonetheless, the hazardous properties of elemental chlorine and consequent potential liabilities work against expansion of transportation and storage of chlorine gas itself.

**Inland Waterway Infrastructure**

Businesses and associations that have an interest in marine transportation via the inland waterway system are almost unanimous in their concern over the less-than-optimal condition of the locks and dams that make much of the system navigable. Such groups include the Waterways Council, the National Waterways Conference, regional port associations, agricultural associations, and private businesses. Lack of trust in the long-term viability of the physical infrastructure is a significant roadblock to investment in businesses that use the system. In fact, one interviewee for this study stated very clearly that all considerations are secondary to the concern over the ability to use the system over the long term. Concerns include the state of major navigation projects such as locks and dams (many of which are in need of significant rehabilitation) and the availability of funds to support maintenance dredging of navigable channels throughout the inland waterways system.
RECOMMENDATIONS (POTENTIAL SOLUTIONS)

Limit Risk to Carriers and Shippers—Institute Insurance Program

Ultimately, to move more hazardous cargoes safely via marine highway services, federal action will be required to clearly define the common carriage and financial obligations of the carriers and to accurately reflect the monetary risk and operating costs of moving such cargoes. As noted earlier, significant policy determinations must be made to augment the economic viability of marine highway services, potentially including policies related to cost-based pricing of hazardous materials transportation services.

The railroads have suggested alternatives for policymakers to consider that might be relevant and adaptable to the marine transportation system:

- Allow carriers to require TIH shippers to indemnify them for liability above a certain reasonable amount.
- Create a fund, to which producers and end-users of TIH materials would contribute to pay for damages above a certain amount. This is similar to Price-Anderson protections in the transportation of nuclear energy waste, where a federal pool of funds was created to compensate victims of a nuclear accident that might take place at any point in the supply chain.
- Create a statutory liability cap for carriers.
- Allow carriers to require shippers to provide evidence of insurance to cover their indemnification requirements (financial responsibility).

This would not absolve carriers of responsibility or remove the incentive to be safety conscious, since carriers would continue to assume liability for the risk of transporting TIH materials at the primary level and accept the normal risks of operations and accidents associated with the transport of any commodity. Carriers would, however, be provided assurance that shippers would share the extraordinary risks presented by a potential release of the extra-hazardous TIH materials they chose to ship.

The Oil Pollution Act of 1990 (OPA 90) might be a good example of an emergency fund that the marine industry already pays into to cover the costs of catastrophic accidents. OPA 90 authorized the creation of the Oil Spill Liability Trust Fund (OSLTF), managed by the National Pollution Funds Center. The OSLTF is financed by industry via a tax of $0.05 per barrel of imported oil, interest on the fund principal, assessed penalties, and cost recovery from responsible parties. The fund totaled a maximum of $2.7 billion as of 2005. The OSLTF can be used for federal cleanup costs and to meet damage claims by government entities, corporations, or individuals. If an accident occurs, the responsible party must cover cleanup and claims up to its liability limit, with the exception of a spill due to gross negligence where liability is not capped.

The Oil Pollution Act also set operational mandates related to vessel construction, crew licensing and manning, and contingency planning in order to reduce the risk of future accidents. In contrast to the OSLTF, which is not a no-fault model, the desirability of a no-fault insurance model for TIH should be evaluated, since the possibility and extent of damage may be affected by the actions of multiple players.

On an international scale, the International Maritime Organization (IMO) developed the IMO Convention on Liability and Compensation for Damage in Connection with the Carriage of
Hazardous and Noxious Substances by Sea (Convention) in 1996. The Convention establishes strict liability for ships carrying hazardous cargo involved in an accident, sets limits to the liability of the ship owner, and makes insurance up to that limit compulsory. In addition, it establishes the International Hazardous and Noxious Substances Fund (HNS Fund) to address excess liability. The HNS Fund is financed by parties that receive specific hazardous cargoes by ship.

Perhaps a similar approach could be applied to encourage domestic waterborne transportation of TIH cargoes domestically. A continuation of the current liability scheme may actually encourage unnecessary use or shipment of TIH materials because it insulates TIH materials producers and receivers from the risks of their commercial decisions by allowing them to shift those risks to the carriers.

**Require Safer Equipment and Technology**

The Federal Railroad Administration (FRA) has published rules that require better puncture resistance for TIH tank cars in either the inner shell or outer jacket, installation of full head shields, and enhanced protection for valves and fittings. They also set a 50-mph speed limit for loaded TIH cars and imposed a requirement to prioritize replacement of all tank cars built from non-normalized steel. The rule specified that these standards should be considered interim tank car standards, applying to all cars built after March 16, 2009. A measure requiring all rail cars to have double shelf couplers is also being discussed. Most TIH releases have been caused by another car in the derailment with a single shelf coupler puncturing the TIH car. This solution, which would dramatically reduce the risk of a puncture, unfortunately would cost the railroad the most money.

While obviously not the intent, such requirements may in fact motivate shippers to consider the marine mode where viable in order to avoid higher rail rates due to the increasing cost of new rail cars. In some cases, the newer, heavier rail cars may not even be able to call on previously served customers. To-date, there has not been much momentum for change among the railroads because their preferred solution where possible is to simply remove TIH from the system rather than “shore up” the system.

Since many rail shipments could not be diverted to water due to geographical constraints, it will be important to assess the potential of new regulations that would have the effect of encouraging more TIH material shipments on roadways—a much riskier operating environment.

**Dilute Ammonia**

Another rail-proposed alternative would be to convert anhydrous ammonia to aqueous ammonia (18% solution in water). Although less hazardous, five times as many rail cars would be required to move an equivalent amount of ammonia, and in most cases the water would have to be removed and processed at the receiving end, making that alternative impractical, uneconomic, and environmentally unfriendly. Should this alternative gain traction, there will be a strong incentive for shippers to consider other alternatives.
Establish Incentives

The government has the ability to encourage positive voluntary behavior through incentives it can offer, such as grants to support the acquisition of equipment or infrastructure modifications and tax incentives to promote facility and supply chain modifications.

A tentative first step in this direction has been taken in the form of America’s Marine Highway grants, with a total amount of $7 million issued by the U.S. Maritime Administration (MARAD) to encourage marine highway service development. Marine highway projects are new waterborne transportation services or expansions of existing services operating between U.S. ports or between U.S. ports and ports in Canada, the Great Lakes, and the Saint Lawrence Seaway. Projects that reduce external cost and provide public benefit by transporting passengers and/or freight (container or wheeled) in support of all or a portion of a marine highway corridor, connector, or crossing (designated by MARAD) may receive support. It is neither the purpose nor the intent of these grants to shift passengers or freight currently moving by water to another water service, but rather to expand the use of marine transportation where landside transportation is currently being utilized and when the water option represents the best overall option. The program gives preference to those projects or components that present the most financially viable transportation services and require the lowest percentage federal share of the costs. Such a program could be modified and augmented to encourage TIH shipments by water.

Restrict Movements through High Urban Threat Areas

One of the more controversial components of a TIH-related policy that Union Pacific Railroad (UP) suggests should be implemented would be a distance threshold for TIH shipments. UP suggests that any request for a TIH rail shipment of more than 1,000 miles would have to be submitted to the STB to justify that the shipment “is in the public interest and cannot be avoided through a less risky or less expensive alternative” (9). Such a policy might even require that shipments over a certain threshold be transported via water when the geography allows.

The Chlorine Institute has made the claim that at least one serious potential “unintended consequence” could flow from this type of policy. It is their opinion that forcing customers to acquire their materials from a closer source because of threshold distances would possibly give an unfair pricing power to nearby suppliers in violation of antitrust laws. However, the literature on the subject of transportation of TIH materials does not address this issue.

Maintain and Improve the Infrastructure and Guarantee Its Condition

For any long-term investment to occur in the marine transportation system, there must be a currently viable infrastructure system in place with some assurance of its continued existence and state of good repair. The Inland Waterways Users Board, in conjunction with the U.S. Army Corps of Engineers, has published a proposed capital investment plan that would prioritize new construction and major rehabilitation projects and provide a path toward making the system more reliable. Their plan also provides a mechanism for increasing the funding available for these projects.

Unfortunately, even though the U.S. Army Corps of Engineers helped develop the plan, its leadership has not championed its adoption, and Congress has not developed any viable alternatives. Given the urgency expressed by the interviewees in this study and by interested
businesses and associations, this problem must be addressed immediately. Until it is addressed, other measures will have little or no effect.

**Encourage the Location of New Plants and Facilities near Marine Terminals**

Economic development (or capital development) grants can be set aside for the use of industries that decide to locate near coastal ports or on inland waterways. They can also be used to assist in the construction of pipelines to marine terminals or in the development of the marine terminals themselves. Measures taken to encourage locations with access to marine transportation will result directly in an increase in marine shipments.

**Integrate the Value of Marine Transportation into National Planning**

Obviously, water transportation cannot serve sections of the country where waterways are not present. Marine vessels typically carry larger quantities of materials and, while in port, must be protected from acts of terrorism (this concern is greatest with regard to large international movements of dangerous cargoes into and out of urban ports). Therefore, adequate security measures will play an important role in developing expanded marine services (10).

A transportation system that offers resiliency and affordable systems redundancy can assist in incident recovery and deter those who seek to do harm to the United States. The value of this resiliency is augmented by the fact that water transportation is often not affected by natural or manmade disasters, or if affected, can frequently resume operations soon after the disabling event. Marine transportation systems must be integrated into disaster recovery planning, and funding must be provided to keep this alternative viable. This is the premise underlying Title XI and Shipbuilding Assistance programs, and the Maritime Security Program (MSP) administered by MARAD. The Title XI Federal Ship Financing Program provides for a full faith and credit guarantee by the United States government to promote the growth and modernization of the U.S. merchant marine and U.S. shipyards. This framework could be used to encourage the construction of more vessels for use in TIH shipments. The MSP provides funding to support the operation of 60 U.S.-flag vessels in the foreign commerce of the United States. Participating operators are required to make their ships and commercial transportation resources available upon request by the Secretary of Defense during times of war or national emergency. This program could also be adapted to a TIH-focused system.

**CONCLUSION**

The obstacles and challenges facing attempts to increase the quantities of TIH materials moved by water are daunting. There simply are no measures that can overcome the geographical dispersion of producers and users and their lack of density along any given corridor, and the fact that both markets are mature. Therefore, significant expansion of transportation of TIH materials via marine highways is not anticipated.

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